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EFFECT OF THICKENER AND GASOLINE QUALITY ON THE PROPERTIES OF NAPALM FUELS

by
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Standard Oil Development Company

Report OSRD No. 4522
Copy No. 44
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EFFECT OF THICKENER AND GASOLINE QUALITY ON THE PROPERTIES OF NAPALM FUELS

Service Directive: CWS-10 and 21

Endorsement (1) From E. P. Stevenson, Chief, Division 11 to Dr. Irvin Stewart, Executive Secretary of the National Defense Research Committee.

Forwarding report and noting:

> "This report describes the effect of gasoline variation on the properties of Napalm fuels. This study was part of a broad investigation embracing all possible causes of variation in the consistency of Napalm fuels. Variation in fuel consistency was wider, the greater the variety of gasoline types used. Fuels high in cyclic hydrocarbons gave higher consistencies than fuels high in paraffins. The effect was much greater in fuels of low concentrations of thickener: the ratio of maximum to minimum consistencies found was only 1.7:1 for 12% Napalm fuels, but was 10:1 for 4% Napalm fuels."

This is a progress report under Contracts OEMsr-354 and 390 with the Standard Oil Development Company.

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EFFECT OF THICKENER AND GASOLINE QUALITY ON THE PROPERTIES OF NAPALM FUELS

ELIZABETH, NEW JERSEY, JULY 6, 1944

NDRC Contracts OEMsr-390 and 354
S.O.D. Projects 30134 and 20907
Report PDN 2575
July 6, 1944

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EFFECT OF THICKENER AND GASOLINE QUALITY ON THE PROPERTIES OF NAPALM FUELS

ELIZABETH, NEW JERSEY, JULY 5, 1944

SUMMARY

A cooperative investigation was carried out by Eastman Kodak* and the Standard Oil Development Company to determine the quality of Napalm thickener currently produced by ten manufacturers under contract with the Chemical Warfare Service and the effect of gasoline quality, moisture content of the soap and thickener concentration on the properties of Napalm thickened fuels. The investigation carried out at the Standard Oil Development Company, which dealt mainly with the effect of gasoline quality, is the subject of this report.

The majority of the thickeners received were of uniform quality, 70% of the samples received from ten manufacturers giving 8% gels having consistencies between 600 and 750 grams Gardner, but 30% of the samples did not conform to specification requirements (500 to 800 grams Gardner).

The properties of Napalm fuels were found to be affected by the type of hydrocarbon employed. Cyclic hydrocarbons tended to give high consistencies while the paraffin, n-heptane, gave the lowest consistency values. Eleven gasolines meeting the requirements for 80 octane general purpose motor fuels all gave thickened fuels having consistencies within relatively narrow limits. Based on a wide variety of automotive fuels exclusive of those meeting the requirements of 80 octane gasoline, highly naphthenic or aromatic gasolines may be encountered which would markedly increase fuel consistency.

The majority of Napalm thickener samples when employed at lower concentrations, e.g., 4% by weight, yielded fuels which tended to decrease in consistency on aging; the decrease amounted to 50 to 70%. This aging phenomenon was the greatest single variable encountered in the investigation.

Considering the variation in thickener and gasoline qualities and the curing effect, the ratio of the maximum to minimum consistency values was found to be about 1.7:1 for fuels containing 12% of the thickener and 10:1 for low (4%) concentration fuels. The variation in consistency at high concentrations (8% of thickener or more) is about equally caused by differences in soap and gasoline quality while at low concentrations at least half of the variation was due to the change which occurred on curing.

* N.D.R.C. Report "An Examination of the Consistency of Napalm Gels," March 13, 1944.

Oxidized gasolines may greatly decrease the consistency of Napalm fuels. However, oxidation-susceptible gasoline can be inhibited at the source with suitable commercial inhibitors as specified for U.S. Army 80 octane general purpose gasoline and should then be suitable for use, unless stored for unusually long periods with excessive exposure.

In view of these results it is recommended that investigations should be undertaken to determine means of diminishing the variation in consistency of Napalm fuels of low concentration.

EFFECT OF THICKENER AND GASOLINE QUALITY ON THE PROPERTIES OF NAPALM FUELS

A. INTRODUCTION

The review* of Napalm manufacture by the committee appointed by Section 11.3 of N.D.R.C., Division 11, indicated that there were variations in production methods and some differences in the properties of the raw materials employed, but all Napalm manufacturers appeared to be producing reasonably comparable products. Since each production method seemed to be under reasonable control, the time appeared opportune to carry out an investigation of thickeners from the various producers with respect to:

1. Soap quality as indicated by the properties of 8% gels tested in accordance with CWS specification 196-131-107.
2. The effect of aging time, temperature, and soap concentration on the consistency of Napalm fuels.
3. Moisture content.
4. The effect of moisture content on the properties of thickened fuels.
5. The relative hygroscopic properties of the various soaps under varying psychrometric conditions.
6. Oxidation susceptibility of the soap and methods of measurement.
7. The effect of gasoline quality on fuel properties.

The investigation was carried out in cooperation with Eastman Kodak, substantially as outlined in the letter from Dr. E. K. Carver to Mr. N. F. Myers dated October 3, 1943, and from Mr. N. F. Myers to Dr. E. K. Carver dated October 14, 1943. Items 1, 2 and 3 were studied at both laboratories in order to determine the reliability and reproducibility of the test methods employed. Item 7 was carried out by the Standard Oil Development Company and the remainder of the program by Eastman Kodak. In view of this arrangement, the results obtained at the Standard Oil Development Company and presented herein should be considered in conjunction with the Eastman N.D.R.C. report, "An Examination of the Consistency of Napalm Gels," March 13, 1944.

* The Manufacture, Properties and Testing of Napalm Soap, O.S.R.D. No. 2036, November 17, 1943.

B. CONCLUSIONS

1. All Napalm samples were within the 0.8% maximum moisture content permitted by specification.

2. Three (30%) of the soaps received from ten manufacturers were outside specification limits for thickening power (500 to 800 grams Gardner), two giving low and one giving high consistency fuels. Seven (70%) of the soaps gave 8% fuels having consistencies between 600 and 750 grams Gardner after aging 24 hours at 150°F.

3. Six of seven soaps received from one manufacturer were also within these limits (600 to 750 grams Gardner).

4. The consistencies obtained after aging the gels for 24 hours at 150°F. were comparable to the values obtained in the surveillance tests. They thus appear to be representative of the ultimate stable condition of the gel and are generally lower and more reproducible than those obtained after aging the gel 48 hours at 77°F. There is some doubt whether the latter test serves any useful purpose as currently prescribed in the CWS specifications. Consequently, it may be advisable both from the point of view of reliability and time saving to delete the 48 hour test at 77°F. and use only the 150°F. test.

5. Napalm is now being produced with sufficient uniformity to permit consideration of selecting soaps that fall within a rather narrow consistency range for use in the field compounding of flame thrower fuels.

6. The three soaps employed in studying the effect of gasoline quality gave 8% fuels of similar consistency, but at other concentrations one soap differed markedly from the other two, giving a very much narrower consistency range at 4% and a higher range at 12% concentrations in all gasolines.

7. Fuels prepared in naphthenic and aromatic type hydrocarbons were of high consistency.

8. Cyclohexane (naphthenic) yielded fuels containing 4 to 12% of thickener which exhibited no significant change in consistency on curing at 70°F. or 125°F. In other pure hydrocarbons and gasolines tested, including highly naphthenic gasoline, there was a decrease in consistency during the aging of fuels containing less than 8% thickener.

9. The decrease in consistency of 4% fuels on curing which occurs in all gasolines may be as much as 70% and is the greatest variable disclosed in this investigation. One of the soaps, however, did not exhibit a curing effect in any of the gasolines.

10. Variation in the composition of the gasoline may affect the consistency of 4% Napalm fuels by a factor of approximately 2. This spread is due mainly to one highly naphthenic gasoline. In other gasolines, particularly the 80 octane general purpose products, the effect of gasoline quality on consistency is relatively small.

11. Considering all soaps, all gasolines, and the curing effect, the ratio of the maximum to minimum consistency values is about 1.7:1 for fuels containing 12% of soap and 10:1 for low concentration fuels (4%). The variation at high concentrations is about equally divided between differences in soap and gasoline quality, while at low concentrations at least half of the variation is due to the change which occurs on curing.

12. The presence of peroxides in gasolines greatly decreases fuel consistency. It is essential, therefore, that all gasolines used in the preparation of Napalm fuels be properly inhibited to prevent oxidation.

13. The results of this investigation agree with previous experience that the solvation rates of Napalm soaps are very sensitive to changes in temperature. This temperature-solvation rate relationship changes so greatly from lot to lot of soap that no general quantitative correlation can be obtained from existing data.

14. With Napalm of current quality, the variations in the consistency of field compounded thickened fuels, particularly at low concentrations, may be so great as to have a relatively large effect on the performance of flame throwers. For this particular application, therefore, it is advisable to select Napalm of greater uniformity.

15. If compounding is carried out in properly equipped plants, 8% fuels having a relatively narrow variation in consistency (150 grams Gardner) can be produced with available Napalm and gasoline provided that adequate methods of control are employed.

C. RECOMMENDATIONS

1. All gasolines used in the preparation of Napalm fuels should be properly inhibited to prevent oxidation of the gasolines as prescribed by the U.S. Army specification No. 2-103B.

2. A review of the inspection data on Napalm manufactured since June 1, 1943, by the various producers appears advisable in order to determine whether sufficient thickener which could yield 8% gels in test gasoline having consistencies between 600 and 750 grams Gardner has been produced to justify selection of lots for use in field compounding.

3. Since preliminary results indicate that dehydrating agents may be effective in reducing the change in consistency which occurs on aging, further investigation should be vigorously prosecuted to determine their practicability.

4. Because of the wide variations in the solvation rates of various Napalms, it appears advisable to undertake a study of the factors affecting the dispersion of Napalm thickener in gasolines.

D. MATERIALS

(a) Napalm Thickener. Samples of Napalm (aluminum soap) thickener obtained from each of ten manufacturers were employed in this investigation.

(b) Pure Hydrocarbons. The pure hydrocarbons which were used to determine the effect of hydrocarbon type on fuel properties consisted of toluene, cyclohexane, di-isobutylene, isooctane, and n-heptane. The latter material was studied with 8% fuels only.

(c) Gasolines. Twenty-three samples of gasolines whose inspections are shown in Tables 1 and 2 were used. Nine of these materials were chosen to include:

(1) A variety of hydrocarbon types.

(2) Several methods of processing.

(3) N.D.R.C. "test" gasoline meeting CWS specification No. 196-131-144 which has been extensively used in determining the quality of Napalm thickeners.

(4) Samples of gasolines used at various plants under contract to CWS for filling incendiary bombs.

One sample of "test" gasoline was also distilled to yield several cuts which were studied to determine the effect of the various fractions on fuel consistency.

Twelve samples represented 80 octane general purpose (pool) gasolines and were obtained from six refineries located in the east, south, midwest, and the Pacific coast. These gasolines, which are similar to those that may be encountered in the field, exhibited similar inspections except for the type and quantity of inhibitors present, and were prepared from eight different crudes or mixtures thereof by the various methods employed in refining automotive fuels. Analysis of one of the samples (No. 25) indicated the presence of a rust preventive oil which affects the consistency of Napalm fuels, hence the data obtained with this sample were excluded.

E. EXPERIMENTAL

The investigation was concerned with a study of the following:

(1) Quality of various thickeners with respect to the consistency and moisture content limitations specified in CWS specification 196-131-107A,

(2) The effect that various gasolines may have on the consistency of fuels prepared with Napalm thickener,

(3) The change in properties of the fuels on aging at 70° and 125°F.,

(4) The effect of temperature on the time required to mix the soap and gasoline.

Fuel consistency and the changes in consistency which occurred on aging were determined by means of Gardner mobilometers which were calibrated and operated in accordance with CWS directive 201B. This directive requires that a cap covering the top of the tube be used when the fuel contains more than 9% of thickener, in order to prevent the gel from being spilled from the tube when the plunger is raised. During the course of the investigation, it was found that different types of caps were used by Eastman Kodak and Standard Oil Development Company. In the latter case, the cap sits loosely on the top of the mobilometer tube while Eastman Kodak used a plug that is inserted into the tube and comes to rest on the gel. As a result of the difference in techniques, the consistencies of gels containing 10% or more of thickener determined by the Eastman procedure were appreciably higher than those obtained at Standard Oil Development Company. With fuels containing 8% or less of thickener comparable results were obtained in the two laboratories. The moisture contents of the soap samples were determined by a modified Dean and Stark procedure as described in CWS specification 196-131-107A while the gasoline inspections were obtained by methods commonly employed in the petroleum industry.

In the evaluation of the quality of the thickeners, the fuels (8% thickener) were prepared with N.D.R.C. test gasoline aged at 150°F. and 70°F. and tested in accordance with the above mentioned CWS specification. Since the time required to disperse Napalm is dependent upon the hydrocarbon composition of the gasoline, all fuels used in the surveillance study were compounded at such temperatures that 8% gels could be prepared within 5 minutes. In most cases the temperatures were between 75 and 90°F., but with di-isobutylene and iso-octane the temperature was increased to 100 and 125°F., respectively. Fuels

employed in the surveillance study contained 4, 8 and 12% by weight of thickener. With each gasoline, all three batches were prepared at the same temperature using soaps from McGean Chemical Company, Harmon Color Works, and Imperial Paper and Color Company, which represent three methods of manufacture. In the case of "test" gasoline No. 14, the fuels contained 4, 6, 8, 10, 12 and 14% by weight of thickener.

Immediately after preparation the fuels were divided into pint Mason jars in which they were stored at 70 and 125°F. while one sample of each of the 8% fuels was cured in a steel tube for 24 hours at 150°F. At intervals varying from one to thirty-two days, samples were examined for consistency in the Gardner mobilometer. During the course of the investigation it was discovered that there was appreciable evaporation from the jars even when the caps were tightened by means of a wrench. As a result, some of the consistency values are erroneously high, especially after 32 days storage at 125°F.

The setting time of certain soaps was determined by adjusting 460 grams of gasoline to the desired temperature, then adding 40 grams of thickener. The mixture was stirred until there was no evidence of settling, then tested once per minute for setting time with the aid of a 60 degree conical funnel having an outlet of 5/8 in. I.D. and 3/4 in. length. The interval in minutes from addition of the soap until less than 90% of the mix would flow through the funnel in 15 seconds represented the setting time.

Table A

CONSISTENCY OF 8 PERCENT NAPALM FUELS CONTAINING SOAPS FROM VARIOUS MANUFACTURERS

(Tested in accordance with C.W.S. Specification 196-131-107A)

Soap Manufacturer	Soap Lot No.	Consistency-Grams Gardner 24 hours at 150°F. Individual	24 hours at 150°F. Ave.	48 hours at 77°F. Individual	48 hours at 77°F. Ave.	Moisture % (c)
Oronite (a)	J-33-C	680 710	695	800 740 840	793	0.4
Oronite (b)	J-33-C	805 800 775	793	975 925 915	938	-
Ferro	184	655 680 660	665	775 775 640	730	0.8
McGean	462	660 670 640	657	615 675	645	0.8
Harmon	R11285	670 675 665	670	675 665 695	678	0.6
Pfister	N-3-2432-94	665 665	665	660 710	685	0.5
Imperial	NR-232	640 610 645	632	665 735 730	708	0.6
Colgate	N-3-2854-56	585 625	605	685 740	713	0.3
Nuodex	19149	740	740	730 730	730	-
Nuodex	19162	730	730	720 720	720	-
Nuodex	19812	670 670	670	660 710	685	0.7
Nuodex	19889	655 690	673	705 690	698	0.7
Nuodex	19839	670 675	673	675 665	670	0.7
Nuodex	20532	630 600	615	625 645	635	-
Nuodex	21318	525 540	533	515 530	523	-
Cal. Ink.	98	480 475	478	585 610	598	0.6
Eakins	N-3-2981-431	415 450 430 475	443	560 610 560 625	589	0.6

(a) As received.
(b) Sample thoroughly mixed at Eastman Kodak
(c) ASTM D95-90 as modified by CWS.

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F. DISCUSSION

(a) Thickener Quality

The results of tests carried out with the various soaps in accordance with CWS specifications are shown in Table A, opposite. All soaps examined were within the maximum allowable moisture content of 0.8 percent and they exhibited, in general, similar consistencies after aging 24 hours at 150°F. Sixty percent of the soaps illustrative of products from ten manufacturers, gave 8% fuels having consistencies between 630 and 675 grams Gardner, while 70% were within the range of 600 to 750 grams. Of the seven lots received from one manufacturer (Nuodex), between June 1, 1943, and February 1, 1944, six (86%) were within the consistency range of 600 to 750. Three of the samples examined were off grade, two giving 8% fuels below the 500 grams specified and one yielding consistencies above 800 grams, particularly when aged 2 days at 77°F. With the latter sample (Oronite), reproducible results could not be obtained at either the Eastman Kodak or Standard Oil Development Company laboratories even when tests were carried out on a portion of the soap which was carefully blended. Both laboratories were in agreement that 8% gels containing the Oronite soap possessed consistencies above 800 grams in the 77°F. test.

There is considerable variation in the consistency values obtained after aging 48 hours at 77°F., sometimes amounting to 100-150 grams even with the same soap as illustrated by the results obtained with the Ferro thickener. It has been the experience with 8% gels in this laboratory that about one batch in four cured at 70-80°F. may be expected to deviate up to 150 gms. from the average of the other three. It is questionable, therefore, whether this method of test is sufficiently reliable in evaluating the quality of Napalm thickener.

These data indicate that the manufacture of Napalm has progressed to the stage where uniform, reproducible soaps are being manufactured and it may be expected that approximately 75% of the Napalm output from the majority of manufacturers will give 8% gels in gasoline which have consistencies within the restricted range of 600 and 750 grams Gardner. Consequently, it would appear feasible to select soaps of this quality for use in the preparation of flame thrower fuels provided that those lots of soap from a given manufacturer which are outside this range but within the specification limits can be directed to the preparation of fuels for incendiary bombs.

(b) Effect of Gasoline Quality on the Properties of Napalm Fuels

Samples of Napalm thickener from three producers (Harmon, McGean and Imperial) and representing three methods of manufacture were dispersed in a variety of hydrocarbons to

TABLE B

CONSISTENCY (GRAMS GARDNER) OF NAPALM FUELS IN "TEST" GASOLINE #14 USING MC GEAN, HARMON AND IMPERIAL SOAPS

% Soap	4		6		8		10		12		14	
Storage Temp.°F.	70	125	70	125	70	125	70	125	70	125	70	125
McGean Soap												
Days Aging												
1	185	220	405	475	710	685	1105	1180	1360	1425	1720	1760
2	180	125	390	390	675	760	1025	970	1330	1280	1590	1680
4	250	130	405	350	705	710	1060	945	1300	1280	1740	1560
8	230	100	455	430	745	755	1000	1140	1440	1650	1985	1850
16	200	100	450	360	745	710	1040	1110	1410	1420	1930	1940
32	210	110	570	415	800	800	1175	1110	1220	-	1740	1910
Harmon Soap												
Days Aging												
1	170	150	470	375	850	755	1070	1180	1400	1425	1725	1760
2	150	105	380	430	825	635	1060	1035	1590	1435	1840	1640
4	110	95	490	400	750	610	1015	1085	1375	1360	1730	1815
8	120	90	380	420	790	630	940	925	1330	1500	1740	1810
16	95	90	375	330	780	635	820	1110	1330	1320	1685	1850
32	110	90	340	370	650	600	950	1065	1420	1390	1790	1670
Imperial Soap												
Days Aging												
1	74	80	350	425	705	750	1120	1000	1400	1120	1630	1510
2	60	74	320	440	810	645	1025	1025	1340	1215	1600	1420
4	61	62	345	345	760	625	1050	1070	1330	1410	1530	1950
8	68	69	275	370	655	675	1050	890	1220	1460	1300	1640
16	85	65	325	605	690	730	975	1100	1160	1570	1545	2120
32	90	70	295	1030	700	770	920	980	1160	1370	1660	2070

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determine the effect of hydrocarbon type and gasoline quality on the consistency and stability of Napalm fuels. Gels containing 4, 8 and 12% by weight of thickener were examined for consistency after curing 2, 16 and 32 days at 70°F. and after 6, 16 and 32 days at 125°F. and, in addition, 8% fuels were tested after 24 hours at 150°F. In the case of "test" gasoline a more extensive surveillance study was carried out in cooperation with Eastman Kodak using gels containing 4 to 14% of thickener in 2% increments and aged from 1 to 32 days in order to determine the degree of reproducibility that may be expected between laboratories. During a conference with the Eastman group it was found that the data were reasonably comparable, the deviations being attributable to evaporation which occurred from the imperfectly sealed containers.

The results of the study (Table B, opposite) indicated that:

(1) All three soaps gave gels of similar consistency when aged under similar conditions.

(2) With the Harmon and McGean soaps, the percentage change in consistency of the fuels on aging increased with decrease in concentration of the thickener, and amounted to less than 15% for fuels containing 14% by weight of thickener and about 50-70% for fuels containing 4% of thickener.

(3) The Imperial soap exhibited similar behavior at higher concentrations, but the 4% fuels showed practically no aging effect and their consistencies were slightly lower than those obtained with Harmon and McGean soaps. Absence of the curing effect is a highly desirable property of thickeners that are to be used in preparing flame thrower fuels.

The same general properties were exhibited in fuels prepared with the various gasolines and hydrocarbons (Tables 3 and 4 appended) with the exception of:

(1) Cyclohexane (Sample No. 1) which gave fuels that within the precision of the test method, did not change in consistency on aging.

(2) Toluene (Sample No. 3) and the relatively aromatic hydroformed naphtha (Sample No. 16) which yielded fuels exhibiting rather limited changes in consistency on aging.

The consistencies of fuels prepared in various fractions of test gasoline (Samples 13, 14 and 20, Table 3 appended) were found to be similar to those obtained with the whole gasoline (Sample No. 11) which indicated that variations in the volatility of gasolines used in the field would have negligible effect on fuel characteristics.

C O N F I D E N T I A L

Table C

EFFECT OF HYDROCARBONS AND GASOLINE QUALITY
ON THE CONSISTENCY OF NAPALM FUELS

Soap Conc. Wt. %	Consistency (Grams Gardner) Pure Hydrocarbons Min.	Max.	Devia.	All Gasolines Min.	Max.	Devia.	80 Octane Gasolines Min.	Max.	Devia.
4	75	390	315	40	250	210	40	155	115
8	550	1060	510	580	900	320	610	790	180
12	1300	2230	930	1160	1700	540	-	-	-

Variables (1) Three soaps.

(2) Aging from 2 days at 70°F. to 16 days @ 125°F.

(3) Four pure hydrocarbons. Toluene
Cyclohexane
Isooctane
Diisobutylene

(4) Twelve uninhibited gasolines representing Straight Run, Cracked, Hydroformed and Mixed process products. Also highly naphthenic, paraffinic and aromatic types of hydrocarbons.

(5) Eleven 80 octane general purpose (pool) gasolines containing various inhibitors and representing six refineries located in the east, midwest, south and west coast. The products represent various methods of processing from 100% straight run to 100% cracked and mixed products from cracking, straight run, reforming and hydroforming.

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C O N F I D E N T I A L

In Table C, opposite, and in Figure 1, following, the overall variation in the consistency of thickened fuels is shown, including variations due to:

(1) The three thickener samples,

(2) The curing effect as shown by the change in consistency on aging from 2 days at 70°F. to 16 days at 125°F.,

(3) Hydrocarbon composition.

In Figure 1, the broken lines define the variation in the consistency of Napalm fuels which was caused by variations in the properties of all thickeners and gasolines studied (pure hydrocarbons excepted) and aging of the fuels until they had reached their ultimate, stable consistency. For example, a fuel prepared with 8% by weight of a high thickening power soap in a gasoline which tended to give high viscosity fuels would yield a product having a consistency of 1060 grams Gardner whereas a fuel prepared with a low thickening power soap in a gasoline giving low viscosity fuels would yield a product having a consistency of 480 grams Gardner. The solid lines define the range of consistency caused by similar variables except that only the Harmon, McGean and Imperial soaps were employed. These data (Table C and Figure 1) show that:

(1) The pure hydrocarbons tested exhibited a higher maximum and a greater deviation in consistency than the regular gasolines.

(2) The consistency of Napalm fuels was markedly affected by the composition of the hydrocarbon in which the thickener was dispersed (Table 3 appended). The high consistency gels were obtained with cyclic hydrocarbons such as cyclohexane and toluene, while n-heptane (8% gels) gave low values with the branch chain paraffin iso-octane and the unsaturated di-isobutylene giving fuels of intermediate consistency.

(3) The deviation in consistency due to variations in the properties of gasolines was about two-thirds of that found with pure hydrocarbons and when consideration is limited to the general purpose 80 octane gasolines which are most likely to be encountered in the field, the deviation was only about one-third. For example, with 8% gels, the deviation in consistency was 510 grams for pure hydrocarbons, 320 for all gasolines and 180 grams for general purpose gasolines. The results obtained with the general purpose gasoline No. 25 (Table 2) were not included because this material was found to be contaminated with a rust preventive oil which would affect the consistency of Napalm fuels.

FIGURE 1

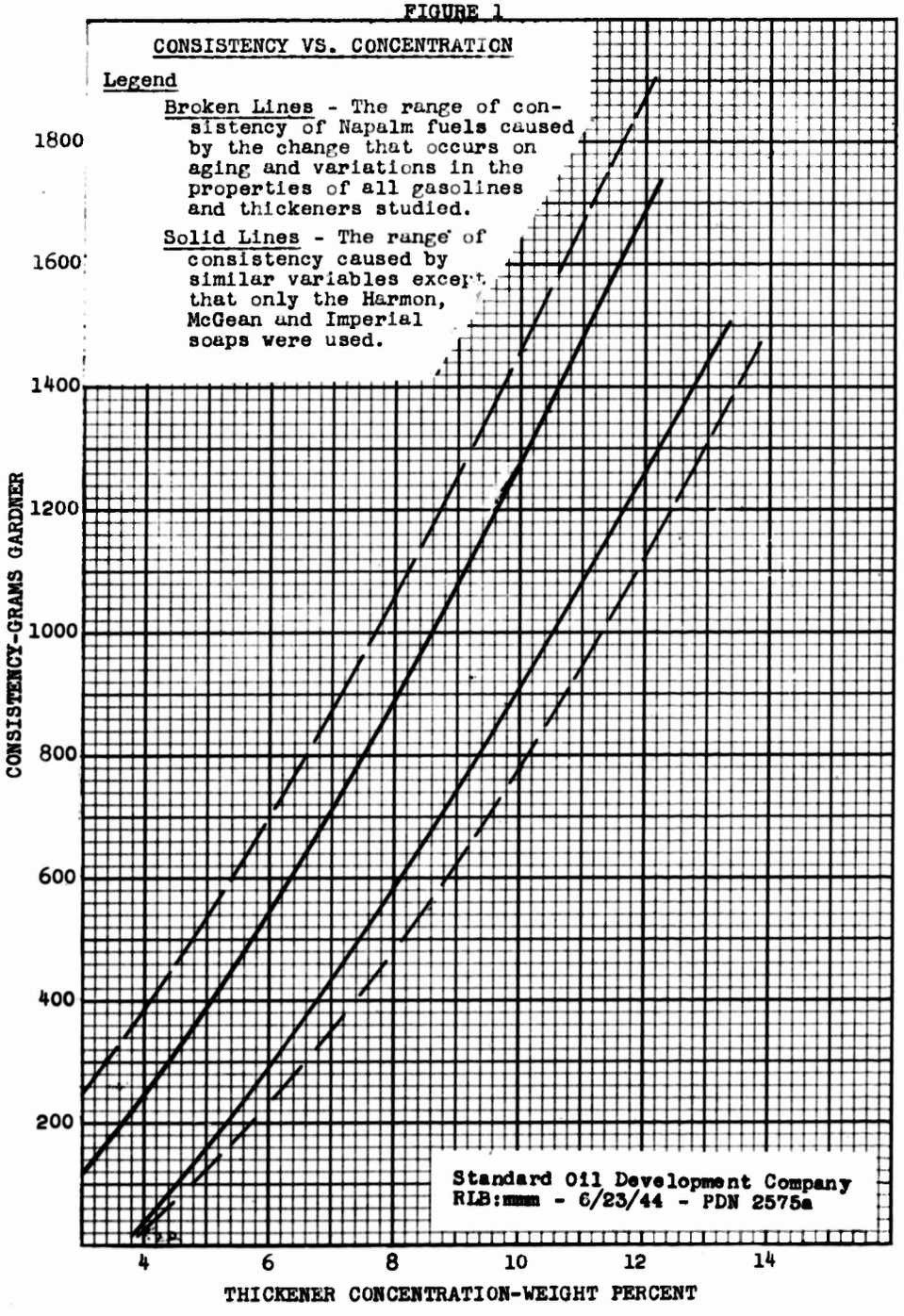
CONSISTENCY VS. CONCENTRATION
Legend
Broken Lines - The range of consistency of Napalm fuels caused by the change that occurs on aging and variations in the properties of all gasolines and thickeners studied.
Solid Lines - The range of consistency caused by similar variables except that only the Harmon, McGean and Imperial soaps were used.
CONSISTENCY-GRAMS GARDNER
1800
1600
1400
1200
1000
800
600
400
200
4
6
8
10
12
14
THICKENER CONCENTRATION-WEIGHT PERCENT
Standard Oil Development Company
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Table D

EFFECT OF GASOLINE QUALITY ON THE PROPERTIES OF NAPALM FUELS

Thickener Conc. Wt. %	Consistency (Grams Gardner) Using Three Soaps and Aging from 2 Days at 70°F. to 16 Days at 125°F. in the Gasolines											
	Naphthenic* (8)			Hydroformed* (16)			"Test" Gaso.*(11)			C.W.S.* (19)		
	Min.	Max.	Diff.	Min.	Max.	Diff.	Min.	Max.	Diff.	Min.	Max.	Diff.
4	90	250	160	130	235	105	60	250	190	50	225	175
8	685	955	275	630	755	125	630	810	180	615	810	195
12	1430	1695	265	1380	1680	300	1320	1590	270	1350	1605	255

* Numbers refer to Table 1.

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(4) Variations in the thickening power of the soap greatly increased the deviation in the consistency of Napalm fuels. The deviation for 8% gels prepared with three soaps and all gasolines was 320 grams whereas the deviation was increased to 580 grams when all soaps were considered (Figure 1).

The effect of gasoline quality is more specifically illustrated by the data of Table D, opposite, and Figures 2, 3 and 4, following, in which soap concentration is plotted against consistency. The dotted lines show the consistency range of fuels prepared in "test" * gasolines and the solid lines represent the overall range for all gasolines studied. These data illustrate that:

(1) With one soap and very similar "test" gasolines there is an appreciable variation in consistency at any given concentration, as illustrated in Figures 2, 3 and 4.

(2) There are no significant differences between the minimum consistency values obtained with various gasolines, but there is a very pronounced difference in the maximum values (Figures 2, 3, and 4). This latter deviation is due largely to the high consistency values obtained with one naphthenic gasoline.

(3) In comparison with the Harmon and McGean soaps, the Imperial thickener yielded fuels exhibiting a wide range of consistency at high concentrations and a relatively narrow range at low concentrations.

(4) The aromatic hydroformed naphtha yielded fuels which exhibited a smaller change in consistency on aging than those obtained from any other gasoline (Table D).

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* As prescribed by CWS Specifications 196-131-144 and 196-131-107

- -

FIGURE 2

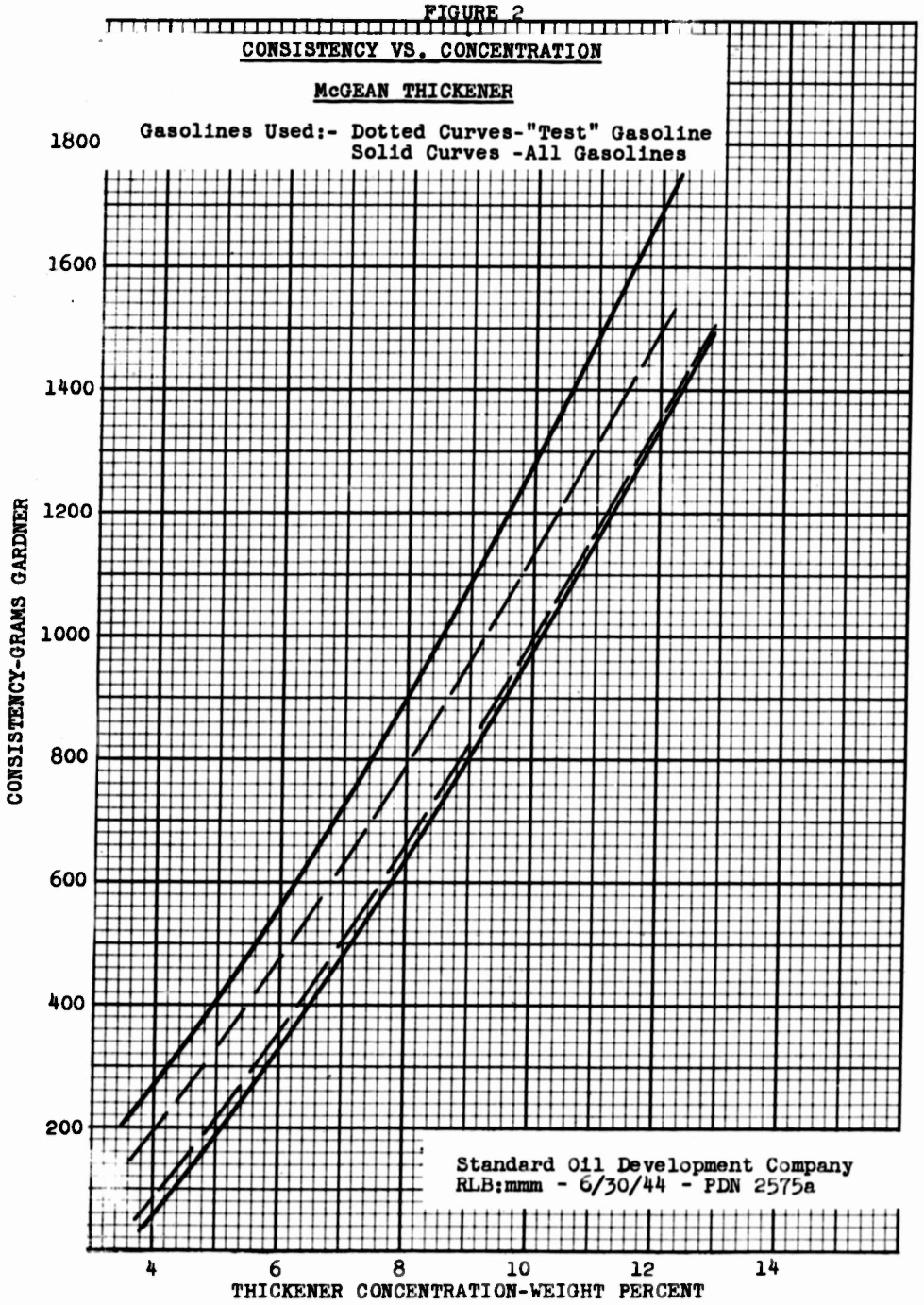
CONSISTENCY VS. CONCENTRATION
McGEAN THICKENER
Gasolines Used:- Dotted Curves-"Test" Gasoline
Solid Curves -All Gasolines
CONSISTENCY-GRAMS GARDNER
1800
1600
1400
1200
1000
800
600
400
200
4
6
8
10
12
14
THICKENER CONCENTRATION-WEIGHT PERCENT
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FIGURE 3

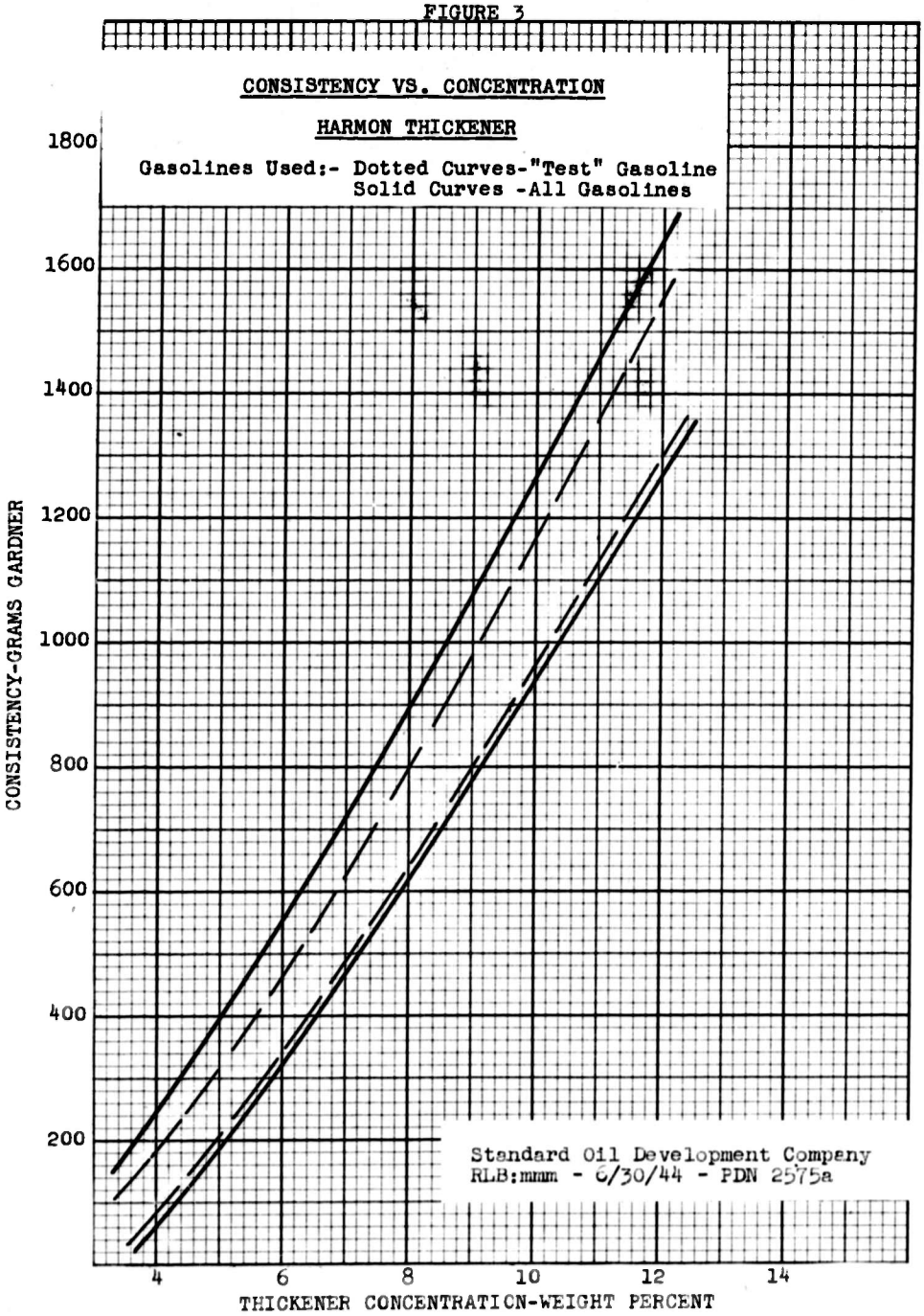
CONSISTENCY VS. CONCENTRATION
HARMON THICKENER
Gasolines Used:- Dotted Curves-"Test" Gasoline
Solid Curves -All Gasolines
CONSISTENCY-GRAMS GARDNER
1800
1600
1400
1200
1000
800
600
400
200
4
6
8
10
12
14
THICKENER CONCENTRATION-WEIGHT PERCENT
Standard Oil Development Company
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FIGURE 4

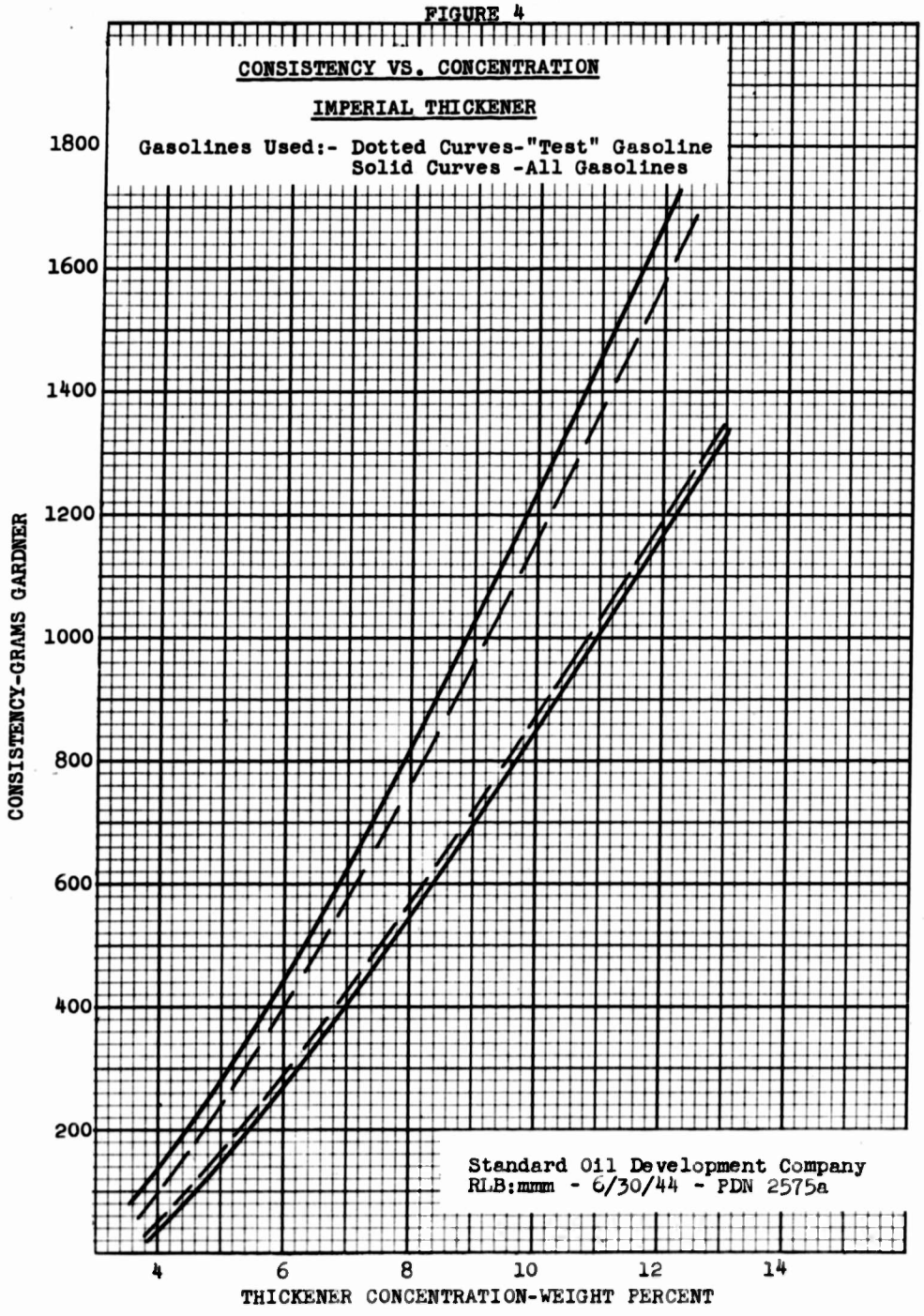
CONSISTENCY VS. CONCENTRATION
IMPERIAL THICKENER
Gasolines Used:- Dotted Curves-"Test" Gasoline
Solid Curves -All Gasolines
CONSISTENCY-GRAMS GARDNER
1800
1600
1400
1200
1000
800
600
400
200
4
6
8
10
12
14
THICKENER CONCENTRATION-WEIGHT PERCENT
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Table E

EFFECT OF THICKENER AND GASOLINE QUALITY ON THE PROPERTIES OF NAPALM FUELS

Thickener Conc. Wt. %	(a) Consistency (Grams Gardner) Resulting from Combinations of: One Soap (b) One Gasoline (c) Min.	Max.	Diff.	One Soap (b) All Gasolines Min.	Max.	Diff.	Three Ave. Soaps (d) All Gasolines Min.	Max.	Diff.	All Soaps (e) All Gasolines Min.	Max.	Diff.
4	90	150	60	65	250	185	40	250	210	40	415	375
8	610	820	210	610	885	275	580	955	375	480	1040	560
12	1320	1590	270	1260	1590	330	1150	1700	540	1100	1910	810

(a) Includes aging effect occurring between 2 days at 70°F. and 16 days at 125°F.
(b) Harmon Thickener.
(c) "Test" Gasoline.
(d) Harmon, Imperial and McGean.
(e) Maximum value with Oronite and minimum value with Eakins thickener.

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In order to determine the maximum variation in consistency that may be encountered due to aging and changes in soap and gasoline quality, a study was made of combinations of:

(1) A high thickening power soap (Oronite) dispersed in the naphthenic gasoline.

(2) A low thickening power soap (Eakins) dispersed in gasoline No. 23.

When these results are considered, the overall variation in consistency (Table E, opposite, and Figure 1 dotted lines) is nearly twice as great as was obtained with the three average soaps (Harmon, Imperial and McGean). These data also indicate that gasoline quality has a relatively small effect on the consistency of fuels containing 8% or more of thickener in comparison with that caused by variation in thickener quality. The general conclusions from the preceding discussions are:

(1) The majority of 80 octane all purpose gasolines have a relatively minor effect on fuel consistency, but gasolines may be encountered occasionally that will yield high consistency fuels.

(2) The greatest change in consistency that may be expected under field conditions is due to variations in the thickening power and curing rates of different lots of soap.

(3) The percentage variation in consistency due to aging increases rapidly with decrease in the proportion of thickener employed.

(c) Significance of Variation in Fuel Consistency on Performance

Fuels for incendiary bombs are prepared at plants where test methods can be employed to determine the proportions of thickener and gasoline which are necessary to yield fuels having consistencies within specified limits and variations in the gasoline or thickener can be controlled reasonably well. This also applies to flame thrower fuels which can be compounded at plants suitably equipped to exercise the necessary control of product quality. When, however, fuels are compounded in the field using the gasolines and soaps available and in fixed ratio, then the variations in fuel consistency may affect flame thrower performance. Since the variations are greatest at low concentrations, the greatest effect may be expected in the performance of portable flame throwers. According to present information, the consistencies of 4% Napalm fuels should fall within 40 and 150 grams Gardner if portable flame throwers are to approach optimum performance. Since it is impracticable to control the

quality of gasolines in the field, it is necessary that variations in soap quality be limited. In view of the fact that the majority of soaps now manufactured yield 8% gels having consistencies between 600 and 750 grams Gardner, it appears feasible to select for field use only those lots that are within this range. It is also necessary to reduce the change in consistency of Napalm fuels which occurs on aging and results recently obtained by Eastman Kodak indicate that this may be accomplished by addition of dehydrating agents to the soap. In order to determine the practicability of these methods it is suggested that:

(1) The inspection records of the various manufacturers be reviewed to ascertain whether there is sufficient soap capable of giving 8% gels with consistencies between 600 and 750 grams to render soap selection practicable.

(2) The effect of dehydrating agents on the quality of Napalm fuels should be thoroughly and vigorously investigated.

(d) Effect of Oxidized Gasoline on Napalm Consistency

During the course of a previous investigation* of the effect of gasoline quality on the consistency of Napalm fuels, it was found that a steam cracked distillate tended to give fuels of low consistency. Since this material contained a relatively large amount of unsaturated hydrocarbons and it had been aged to the point where it contained considerable oxidation products, a study was made of the effect of gasoline oxidation on fuel properties. Fuels were prepared in a similar material, part of which was inhibited to prevent oxidation while other portions were uninhibited and allowed to oxidize. At various stages of oxidation as represented by the peroxide number, ** 8% Napalm fuels were prepared and aged 24 hours at 150°F. The results were substantiated by later studies using a sample of gasoline obtained from a plant (Kilgore) engaged in filling and assembling M69 incendiary bombs. This gasoline and two others (Rocky Mountain Arsenal and United Wall Paper) were forwarded by the CWS Technical Command as examples of gasolines which might give low consistency Napalm fuels. These gasolines were included in the surveillance study and showed originally no evidence of adverse effects (Table 3).

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* Effect of Gasoline Quality on Napalm Thickened Fuels - PDN 1418, July 31, 1943.

** Peroxides and Gum in Gasolines, Yule and Wilson, Ind.Eng.Chem. 23. 1254, (1931).

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Table F

EFFECT OF OXIDIZED GASOLINES ON THE CONSISTENCY OF NAPALM FUELS (8% GELS)

Thickener Source	Nuodex 17962				Imperial NR-232		Harmon R11285	
Gasoline	NDRC "Test"	Steam Cracked Naphtha Inhibited	Uninhibited		NDRC "Test"	Kilgore 19	NDRC "Test"	Kilgore 19
Peroxide No. *	0	0	17	47.5	0	39	0	70
Grams Gardner after 24 hours @ 150°F.	635	630	510	175	645	310	670	110

* Gram equivalents of oxygen per 1000 liters of gasoline.

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Three to four months later one of these gasolines was found to be highly oxidized (No. 19, Table 1). Fuels were immediately prepared with this gasoline using the Imperial soap, while two weeks later similar fuels were prepared with the Harmon soap. In both cases it was found that low consistency fuels were obtained (Table F, opposite) and furthermore the decrease in consistency appeared to be proportional to the degree of gasoline oxidation (Figure 5, following).

Results obtained at Eastman Kodak during their psychrometric studies indicated that 0.5% increase in the moisture content (0.44% oxygen equivalent) of the Imperial soap would decrease the consistency of 8% gels to 380 grams Gardner. This effect is roughly comparable to the value of 310 grams obtained with the Imperial soap in a gasoline having a peroxide number of 39 which represents oxygen equivalent to 0.47% by weight of the soap employed in the preparation of 8% fuels.

In view of these results, it is just as important to prevent undue oxidation of the gasoline as it is to control the moisture content of the soap. Fortunately, motor gasolines used by the armed forces are well inhibited, consequently very little difficulty due to oxidized gasoline may be expected in field compounding. Where fuels are prepared at plants either for incendiaries or flame throwers, it is strongly recommended that the gasoline be inhibited to give a minimum breakdown of 480 minutes ASTM as specified for 80 octane general purpose motor gasoline.

Since oxidized gasolines had such a pronounced effect on fuel consistency, consideration was given to moisture and phenols present in the gasolines, but there was no apparent relationship between phenol or dissolved water content and the consistency of Napalm fuels.

FIGURE 5

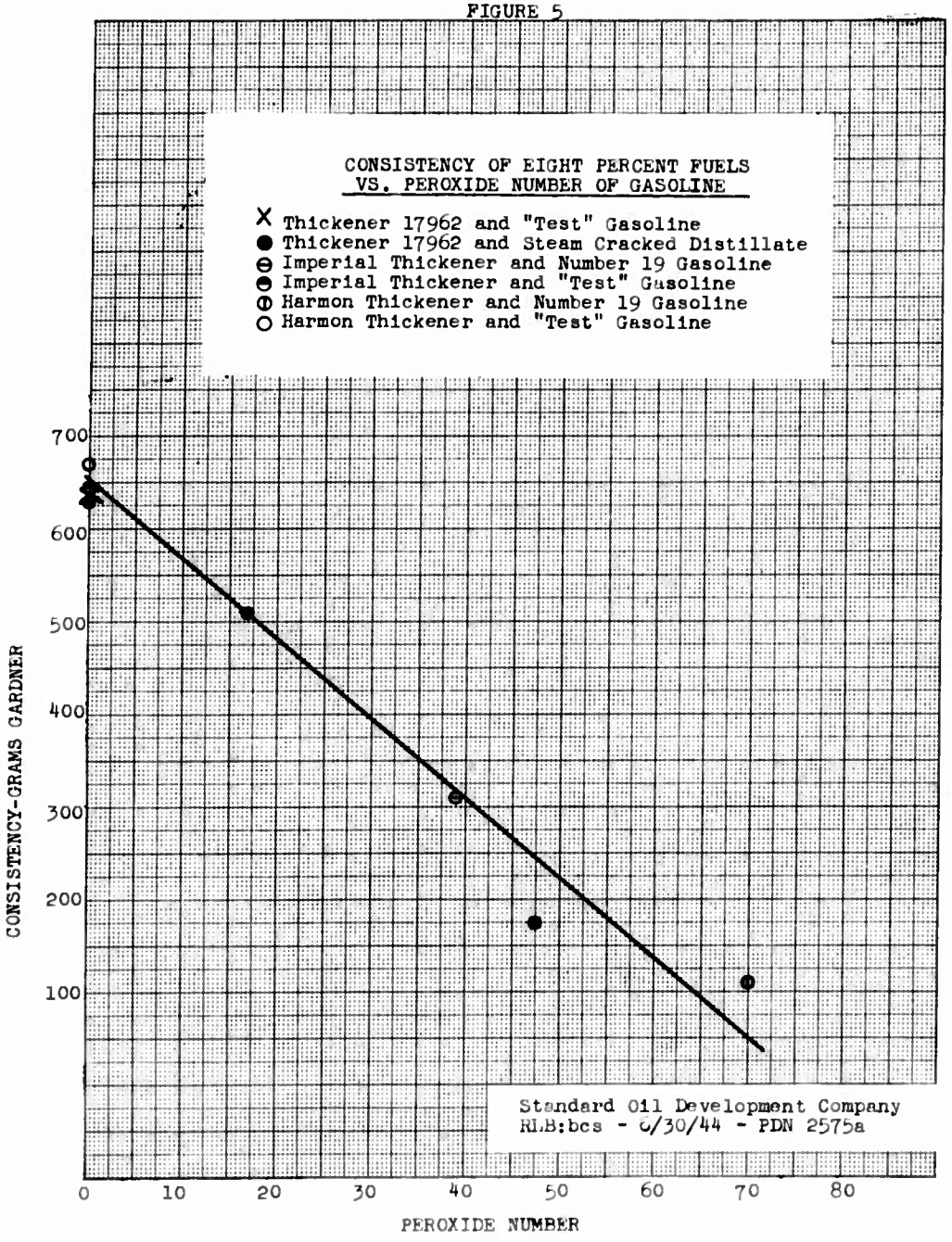
CONSISTENCY OF EIGHT PERCENT FUELS
VS. PEROXIDE NUMBER OF GASOLINE
X Thickener 17962 and "Test" Gasoline
● Thickener 17962 and Steam Cracked Distillate
⊖ Imperial Thickener and Number 19 Gasoline
◒ Imperial Thickener and "Test" Gasoline
◐ Harmon Thickener and Number 19 Gasoline
○ Harmon Thickener and "Test" Gasoline
CONSISTENCY-GRAMS GARDNER
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
PEROXIDE NUMBER
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Table G

EFFECT OF TEMPERATURE ON SETTING TIME OF 8% FUELS (a)

Thickener		Setting Time in Minutes at Temperatures, °F. Shown						
Manufacturer	Lot Number	40°	50°	60°	70°	77°	90°	100°
Ferro	184	405	96	2.5	0.4	0.3	1.0	2.5
Pfister	N-3-2432-94	600	100	25	2	1.4	1.0	1.3
Harmon	R11285	330	93	16	4	3.0	3.0	2.5
Imperial	NR-232	180	60	7	5	7.0	3.0	3.8
Nuodex	19889	315	25	11	8	9.0	5.0	11.2

(a) Tests carried out with "Test" Gasoline (Sample 11, Table 1)

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(o) Effect of Temperature on Setting Time

Some of the soaps have been examined to determine the effect of temperature on their solvation rates in test gasoline (Sample 11, Table 1) using 8% by weight of the thickener. With two of the soaps (Imperial and Nuodex) a peculiar variation was found at temperatures between 70 and 90°F. (Table G, opposite, and Figure 6, following). This relationship was reproducible but it has never been observed in any previous work. The behavior of the remaining soaps (Figure 6) was found to be in agreement with past experience, namely:

(1) Napalm from various manufacturers exhibited rather wide variations in solvation rate.

(2) In most instances the setting time was at a minimum between 70 and 90°F.

(3) At low temperatures (below 60°F.) the setting time increased very rapidly with decreasing temperature.

A study is in progress to determine the relationship between temperature and solvation rate at lower concentrations of thickener. While this investigation is incomplete, experience to date indicates that within the temperature range of 70-90°F., 4% fuels must be mixed about three times as long as 8% fuels if reasonably uniform products are to be obtained. It follows, therefore, that soaps having a setting time of 10 minutes at 77°F. would have to be mixed at least 30 minutes at temperatures above 70°F. in order to compound fuels containing 4% of thickener. It is concluded that:

(1) For the compounding of fuels at various concentrations, the setting time (8% gels) should be within the limits of 2 to 7 minutes.

(2) Compounding should be done at temperatures above 70°F.

(3) A further study of methods of reducing the variability in solvation rates exhibited by various soaps is required. Such an investigation should include the development of (a) simple, improved methods for compounding low consistency fuels and (b) equipment suitable for mixing higher consistency fuels required for mechanized units quickly and in sufficient volume. The latter phase is under study at the Standard Oil Development Company using equipment designed for servicing the mechanized flame thrower.

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FIGURE 6

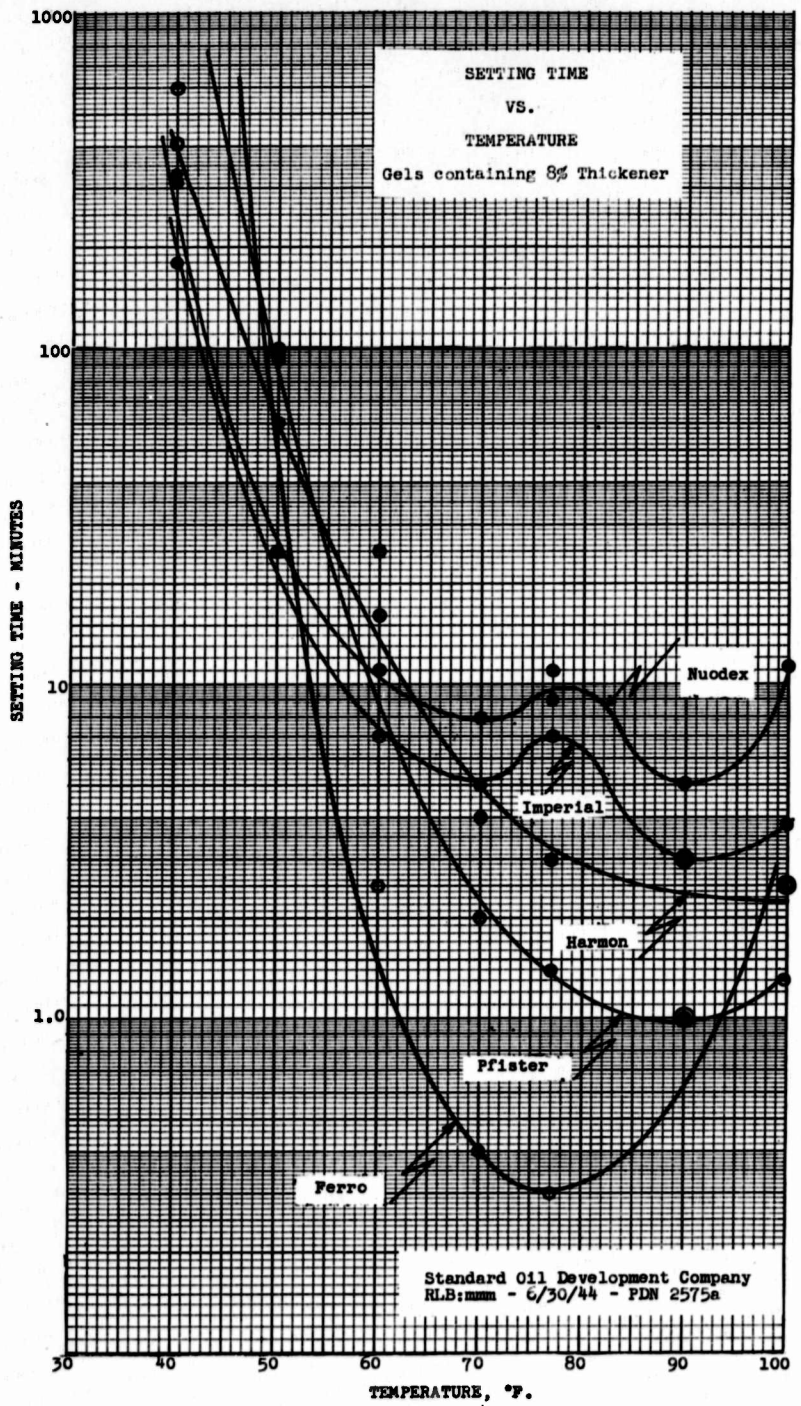
SETTING TIME
VS.
TEMPERATURE
Gels containing 8% Thickener
SETTING TIME - MINUTES
1000
100
10
1.0
Nuodex
Imperial
Harmon
Pfister
Ferro
30
40
50
60
70
80
90
100
TEMPERATURE, °F.
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TABLE 1

GASOLINE INSPECTIONS

Sample No. Hydrocarbon or Gasoline	3 Toluene	1 Cyclo-hexane	4 Diiso-butylene	5 Iso-octane	5 N-Reptane	7 (e) Ref. Fuel M5	8 (b) Sugar-land Nephtha	10 Motor 65 Octane	11 Tested #14 0-100%	20 Tested #14 0-80%	13 Tested #14 30-60%	14 Tested #14 60-90%	18 Tested #13	16 Hydro-formed Naphtha	19 (c) Kilgore Plant	21 (d) United Wallpaper Plant	23 (a) Rocky Mountain Arsenal	- Steam Cracked Nephtha
Distillation - I.B.P., °F.	230.8	-		208	207	135	125	99	93	82	158	239	95	127	107	106	97	104
10% off at °F.	231.4	178		209	207	197	194	127	104	-	167	250	103	180	136	135	135	140
60% off at °F.	-	-		210	207	273	287	225	201	135	176	273	213	216	235	244	244	224
90% off at °F.	231.6	178		210	208	352	340	339	348	188	198	313	347	250	363	376	341	355
F.B.P., °F.	231.8	181		219	228	388	380	390	401	237	223	354	392	309	442	-	380	394
Gravity, °API	31.2	60.5	54.8	71.8	74.5	61.2	53.1	51.0	52.4	77.6	54.5	48.7	51.0	64.6	61.5	51.0	51.3	48.4
Aniline Point, °F.	-	85	111	175	157	140	125	115	97	110	102	82	95	77	97	109	113	3
Reid Vapor Pressure, psi	-	-	-	-	-	2.9	4.5	6.5	11.8	17.2	4.5	0.0	11.9	6.6	9.0	10.7	9.7	5
Refractive Index, D/20°C.	1.4965	1.4270	1.4116	1.3914	1.3879	1.4120	1.4229	1.4140	1.4121	1.3832	1.4047	1.4392	1.4214	1.4228	1.4170	1.4130	1.4109	1.4473
Specific Dispersion	183.5	95.8	87.9	99.3	96.8	106.4	101.0	106.8	108.5	99.4	104.2	115.9	113.8	128.6	107.4	105.7	100.6	
Acid Heat, °F.	22	-	236	1.0	-	0	1.0	65	125	155	106	81	114	16	141	98	135	460
Bromine No., cgs./ml.	0.4	0.0	139	0.8	-	0.2	0.0	21.0	38.0	45	34.4	26.1	36.4	4.2	37.4	34.4	41.2	121
Phenol No. (f)	-	-		-	-	4	0	100	100	86	160	120	100	36	85	100	100	-
Mercaptan Sulfur (g)	-	-	1.0	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Reactive Sulfur (h)	-	-	0.0	-	-	0.5	40	-	1.0	0.6	1.0	0.5	1.5	1.6	2.0	0.0	3.0	0.5
Sulfur - Lamp, %	-	-	-	-	-	0.014	0.100	0.03	0.03	0.017	-	0.051	0.030	0.008	0.043	0.046	0.034	0.035
ASTM Gum, mg./100 ml.	-	-	0.4	0.5	-	1.4	1.4	4	0.6	0.6	2.8	1.2	3.0	8.5	4.0	6.0	1.4	-
ASTM Octane - Clear	-	-	-	-	-	22	64	65	0	77	72	71.2	72	71	70	70	57	79
ASTM Octane + 3 ml. TEL/gal.	-	-	-	-	-	-	77	79		86	84	80	81(k)	86.0	79	81	77	-
Peroxide No. (i)	-	-	0	-	-	0.0	0.0	1.8	0	0.0	0.9	1.3	0.4	0.0	39(m)	1.0(m)	3.7(m)	0.3
Water - Vol.%				-	-	0.002	0.002	0.002	0.002	-	-	-	0.002	0.007	0.005	0.002	0.003	-
Aromatics - % (j)	99+	0	0	1-	0	8	2	10	12	2.6	7	22	18	36	11.0	10.0	2	27

(e) Highly paraffinic naphtha from Michigan Crude.
(b) Highly naphthenic straight run nephtha.
(c) Sample of gasoline used in the Kilgore filling plant for M69 bombs.
(d) Sample of gasoline used in the United Wallpeper filling plant for M69 bombs.
(e) Sample of gasoline used at the Rocky Mountain Arsenal.
(f) Milligrams of tertiary amyl phenol per 100 ml. of gasoline.
(g) Milligrams of mercaptan sulfur per 100 ml. of gasoline.
(h) Milligrams of reactivb sulfur per 100 ml. of gasoline.
(i) Gram equivalents of active oxygen per 1000 liters of gasoline.
(j) Estimated from specific dispersion and bromine number. Approximate precision ± 2%.
(k) With 2 ml. TEL per gallon.
(m) Determined on samples aged for 3-4 months.

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TABLE 2

GASOLINE INSPECTIONS

(80 OCTANE GENERAL PURPOSE GASOLINES)

Sample No.	24	25	26	27	28	29	30	31	32	33	34	35
Origin of Gasoline												
Refining Area	Indiana	Illinois	Texas	Texas	Cal.	Texas	Texas	Texas	New Jersey	So.America	So.America	So.America
Crude Sources	Mid-Cont.	Mid-Cont.	Mid-Cont. West Texas New Mexico	E. & W. Texas	Cal.	Texas La. Ga.	Texas La. Ga.	Texas La. Ga.	Mid-Cont.	Venezuela	Venezuela	Venezuela
Gasoline Composition, Vol.%												
Straight Run	15	8	-	-	-	-	-	-	50	-	-	-
Cracked	85	92	-	90	100	68.5	100	-	50	-	-	-
Reformed	-	-	15	-	-	31.5	-	100	-	-	-	-
Hydroformed	-	-	75	-	-	-	-	-	-	-	-	-
Casing Head	-	-	10	10-C_4+C_5	-	-	-	-	-	-	-	-
Inhibitor Present	D.P.19	UOP 5	D.P. 5	UOP 5	UOP 4	UOP 4	UOP 4	UOP 4	Alpha Naphthol	Trioresol	Trioresol	D.P. 5
Inhibitor Conc., lbs./1000 bbls.	10	25	12	13	11.5	38.4	36	14.4	35	65	145	24.5
TEL, ml./gal.	3.0	3.0	2.8	1.5	2.7	2.0	2.0	2.0	2.5	2.4	2.4	2.4
Inspections												
Distillation - I.B.P., °F.	104	100	109	96	105	108	112	114	105	110	110	108
10% off at °F.	150	142	144	130	141	145	143	150	142	139	139	143
50% off at °F.	230	231	200	220	222	221	212	230	216	202	202	206
90% off at °F.	310	325	292	335	342	313	281	286	318	312	312	305
F.B.P., °F.	365	358	360	392	378	354	332	326	378	365	365	360
Gravity, °API	51.5	59.5	54.4	57.0	59.5	59.9	61.7	58.1	62.6	52.1	62.1	62.2
Aniline Point, °F.	107	105	113	74	97	92	92	88	110	98	98	97
Reid Vapor Pressure, psi/100°F.	7.2	5.8	5.2	8.0	5.4	5.8	5.8	5.9	7.1	5.7	5.7	7.0
Refractive Index, D/20°C.	1.4129	1.4141	1.4055	1.4252	1.4155	1.4151	1.4138	1.4197	1.4089	1.4114	1.4113	1.4117
Specific Dispersion	104.2	105.1	104.5	115.1	102.8	105	104.5	111.1	106.9	105.7	103.7	105.1
Acid Heat, °F.	102	105	60	123	144	132	159	105	72	129	129	117
Bromine No., ogs./100 ml.	40.3	35.0	22.5	39.8	51.8	48.9	55.4	38.3	25.5	42.5	44.0	41.7
Phenol Number	85	100	75	105	100	80	60	80	90	160	160	170
Mercaptan Sulfur	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Reactive Sulfur	1.0	1.5	1.5	3.5	0.5	1.0	0.5	0.5	1.0	9.5	7.5	1.0
Sulfur - Lamp - %	0.035	0.040	0.048	0.062	0.100	0.042	0.041	0.017	0.020	0.090	0.090	0.077
ASTM Gum	3.2	9.8	4.4	8.5	3.8	6.8	3.4	3.4	4.2	4.2	2.0	2.2
ASTM Octane	80	81	80	82	81	80	79	82	80	80	80	80
Peroxide Number	0.6	1.5	0.0	2.2	0.2	0.5	0.9	0.8	0.1	5.6	5.5	0.0
Water - Vol.%	0.004	0.002	0.005	0.004	0.004	0.008	0.007	0.002	0.002	0.005	0.004	0.007
Aromatics - %	5	7	7	18	4	6	6	13	8	7	5	7

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TABLE 3

CONSISTENCY OF NAPALM FUELS PREPARED WITH VARIOUS HYDROCARBONS AND COMMERCIAL GASOLINES

Hydrocarbon or Gasoline	Sample Number (c)	Soap	4% Gels						6% Gels							8% Gels							12% Gels					
			Days at 70°F.			Days at 125°F.			24 Hrs. at 150°F.	Days at 70°F.			Days at 125°F.			24 Hrs. at 150°F.	Days at 70°F.			Days at 125°F.			Days at 70°F.			Days at 125°F.		
			2	16	32(d)	2	16	32(d)		2	16	32(d)	2	16	32(d)		2	16	32(d)	2	16	32(d)	2	16	32(d)	2	16	32(d)
Toluene	5	McGean	270	180	235	190	200	270	980	880	895	1000	910	900	1040	2720	1640	2000	1910	2000	1960							
		Harmon	215	205	215	180	185	180	915	1010	930	935	1085	975	1210	1890	1980	2000	1930	2020	2040							
		Imperial	155	230	145	290	300	425	940	1060	1010	1000	955	835	1010	2230	1700	1900	2150	1730	1910							
Cyclohexane	1	McGean	250	270	270	300	345	405	880	985	980	1285	945	1000	1145	2000	1840	2115	1880	1990	2290							
		Harmon	320	350	350	285	345	455	1025	1065	1090	1170	1150	1130	1240	1990	2070	2170	2370	2130	2170							
		Imperial	220	300	315	300	380	335	1060	1340	1110	1160	1240	1070	1130	2630	2000	2050	1940	2200	2080							
Iso-octane	8	McGean	285	265	215	105	255	290	700	715	700	650	690	870	870	1540	1320	1240	1450	1720	1740							
		Harmon	290	285	235	120	300	155	620	895	835	740	785	960	870	1725	1500	1355	1575	1460	1475							
Dimer	4	McGean	240	200	145	105	140	135	730	720	860	650	730	755	690	1720	1500	1490	1520	1490	1410							
		Harmon	110	85	85	80	85	105	710	670	650	710	740	660	755	1510	1330	1500	1570	1570	1585							
		Imperial	185	115	95	75	75	95	725	955	840	800	645	665	720	1520	1530	1490	1590	1430	1520							
n-Heptane	6	McGean	-	-	-	-	-	-	615	650	675	670	660	650	565	-	-	-	-	-	-							
		Harmon	-	-	-	-	-	-	545	560	530	590	550	545	625	-	-	-	-	-	-							
Ref. Fuel #3	7	McGean	215	195	230	140	125	160	665	665	855	800	760	750	700	1350	1440	1410	1545	1260	1520							
		Harmon	160	145	160	135	115	140	625	695	660	695	675	875	1060	1315	1380	1630	1590	1320	1585							
		Imperial	55	55	55	50	55	75	725	710	645	660	600	625	680	1360	1340	1455	1455	1350	1380							
Sugarland Naphtha	8	McGean	250	245	230	150	155	155	855	820	835	830	765	740	900	1680	1540	1535	1540	1630	1765							
		Harmon	250	135	160	155	155	145	695	885	680	818	710	700	815	1625	1580	1625	1560	1520	1615							
		Imperial	125	54	75	85	90	100	790	955	830	800	685	780	770	1695	1530	1460	1510	1430	1610							
		Cromite	415	325	300	965	155	140		1040	1080	1000	900	890	980	1910	1990	1860	1740	1910	1880							
66 Octane Number	10	McGean	230	150	110	70	80	70	645	750	830	760	730	800	730	1565	1610	1485	1560	1660	1465							
		Harmon	155	90	100	80	85	75	675	765	685	740	645	700	730	1580	1270	1565	1560	1320	1520							
		Imperial	85	80	81	75	70	70	660	720	625	645	645	670	730	1455	1220	1490	1510	1325	1560							
Test 13	15	McGean	215	155	135	110	80	85	720	695	665	780	700	740	670	1500	1470	1570	1530	1380	1415							
		Harmon	220	130	140	120	90	90	760	780	735	740	635	725	755	1520	1340	1480	1300	1370	1590							
		Imperial	75	80	45	80	70	80	640	765	620	630	715	715	745	1390	1430	1440	1415	1490	1610							
Test 14	11	McGean	180	200	210	125	100	110	675	675	745	800	760	710	800	1330	1260	1220	1360	1480	-							
		Harmon	160	85	110	90	90	90	670	680	780	650	610	635	600	1590	1330	1480	1520	1320	1390							
		Imperial	100	90	90	75	55	65	645	810	690	700	645	750	720	1540	1160	1160	1600	1570	1370							
Test 14 (0-60% Cut)	20	McGean	185	180	130	105	180	180	640	690	610	550	540	-	715	1215	1260	1260	1360	1480	1660							
		Harmon	150	115	120	90	95	130	610	715	705	705	725	785	900	1260	1270	1130	1320	1440	1445							
		Imperial	85	85	85	85	74	159	565	585	600	590	675	625	1050	1505	1110	1120	1455	1335	1650							
Test 14 (30-60% Cut)	13	McGean	175	155	150	105	100	95	645	670	710	730	800	720	730	1290	1320	1285	1500	1310	1590							
		Harmon	220	130	140	110	140	-	715	765	685	740	700	720	775	1440	1370	1525	1570	1320	1540							
		Imperial	-	-	-	-	-	-	695	745	715	720	748	690	730	-	-	-	-	-	-							
Test 14 (60-90% Cut)	14	McGean	230	180	155	90	90	80	840	810	825	830	655	765	730	1420	1560	1780	1470	1800	1635							
		Harmon	180	120	130	105	80	80	675	825	755	740	745	655	780	1470	1580	1415	1590	1525	1755							
		Imperial	75	80	45	75	80	75	805	760	730	705	765	740	780	1460	1310	1540	1500	1550	1870							
Hydroformed Naphtha	16	McGean	235	145	155	140	140	145	790	695	770	720	685	660	730	1350	1380	1480	1530	1420	1650							
		Harmon	225	190	155	175	155	220	720	750	745	750	610	765	850	1430	1680	1430	1540	1930	1570							
		Imperial	155	85	120	150	130	135	730	755	665	805	630	920	855	1390	1430	1500	1365	1430	1520							
C.W.S.-Kilgore Plant	19	McGean	225	110	50	55	75	70	690	805	855	730	780	710	705	1350	1460	1435	1600	1305	1435							
		Harmon	125	75	70	65	65	60	590	750	670	690	680	640	715	1400	1360	1390	1420	1390	1470							
		Harmon	-	-	-	-	-	-	110(c)	-	-	-	-	-	-	-	-	-	-	-	-	-							
		Imperial	85	45	44	45	80	82	660	615	-	645	780	565	730	1610	1280	1480	1300	1490	1680							
		Imperial	-	-	-	-	-	-	310(b)	260(b)	-	-	-	-	-	-	-	-	-	-	-							
C.W.S.-United Wallpaper Plant	21	McGean	245	155	85	65	70	75	705	720	715	710	680	835	730	1660	1630	1435	1430	1680	1560							
		Harmon	155	120	50	70	65	80	765	845	705	715	710	630	780	1370	1340	1380	1570	1670	1570							
		Imperial	85	45	52	50	90%	80	680	710	665	680	715	740	785	1660	1295	1440	1580	1300	1380							
C.W.S.-Rocky Mountain Arsenal	25	McGean	245	139	108	95	80	107	645	750	840	755	785	705	765	1410	1480	1680	1265	1400	1710							
		Harmon	150	100	80	80	80	80	605	725	685	665	690	710	735	1350	1330	1230	1300	1660	1565							
		Imperial	80	-	41	55	61	75	710	695	615	580	615	655	655	1430	1190	1305	1355	1280	1280							
		Mains	75	80	40	80	45	40		490	420	365	365	355	380	1130	1080	1000	1130	1240	1000							

(c) Reference to numbers in Table 2.
(b) Used sample of gasoline aged 3-4 months - peroxide number = 39.
(c) Used sample of gasoline aged 4+ months - peroxide number = 70.
(d) Because of imperfectly sealed containers, evaporation occurred occasionally resulting in high consistency values.

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TABLE 4

CONSISTENCY OF NAPALM FUELS PREPARED WITH 80 OCTANE GENERAL PURPOSE MOTOR GASOLINE

Gasoline Sample Number	Soap	4% Gels						24 hrs. @ 150°F.	8% Gels					
		Days @ 70°F.			Days @ 125°F.				Days @ 70°F.			Days @ 125°F.		
		2	16	32	2	16	32		6	16	32(a)	6	16	32(a)
24	McGean							690	660	745	760	635	715	670
	Harmon								715	735	715	630	660	610
25	McGean							470	790	645	680	620	510	660
	Harmon								625	615	600	580	555	460
26	McGean							650	765	715	745	645	-	725
	Harmon								610	620	650	615	620	670
27	McGean							685	710	685	690	755	780	875
28	McGaan							670	700	710	685	755	780	875
	Harmon	155	110	104	90	70	50		705	695	680	700	685	835
29	McGaan							670	680	635	620	710	725	750
	Harmon	135	95	85	80	50	50		690	665	660	660	620	530
30	McGaan							690	720	715	785	-	690	630
	Harmon	150	105	100	90	50	35		705	690	665	660	630	595
31	McGean							730	730	815	785	730	-	915
	Harmon	140	135	130	125	80	75		705	695	695	740	745	750
32	McGean							700	735	730	740	770	725	850
	Harmon	120	110	110	90	70	80		750	720	710	700	-	705
33	McGaan							685	730	715	730	735	745	1000
	Harmon	80	80	65	55	40	50		680	645	680	610	730	520
34	McGean							645	730	695	800	820	1280	1200
	Harmon	140	100	95	70	55	65		740	670	685	660	710	720
35	McGean							690	720	695	820	755	810	785
	Harmon	110	76	65	45	40	45		675	720	685	680	620	610

(a) Because of imperfectly sealed containers, evaporation occurred occasionally resulting in high consistency values.

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AUTHOR(S): Betts, R. L.

ORIGINATING AGENCY: Standard Oil Development Co.

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ABSTRACT:

An investigation was carried out to determine the quality of Napalm thickener and the effect of gasoline quality, moisture content of the soap, and thickener concentration on the properties of Napalm thickened fuels. The majority of thickeners received were of uniform quality, 70% giving 8% gels having consistencies between 600 and 750 grams Gardner. Cyclic hydrocarbons tended to give high consistencies while the paraffin, n-heptane, gave the lowest consistency values. The majority of Napalm thickener samples when employed at lowest consistency values, e.g., 4% by weight, yielded fuels which tended to decrease in consistency on aging. Considering the variation in thickener and gasoline qualities and the curing effect, the ratio of the maximum to ninimum consistency values was found to be about 1.7:1 for fuels containing 12% of the thickener and 10:1 for low (4%) concentration fuels.

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3 / 3

SUBJECT HEADINGS: Fuels, Incendiary - Fortifying (42657); Incendiaries - Physical properties (50961.5)

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(23)* Incendiary Mixtures

Napalm Bombs
Fuel thickeners